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Enabling Energy Management for Planning Energy-Efficient Factories

Egon Müller, Romina Poller*, Hendrik Hopf, Manuela Krones

Department of Factory Planning and Factory Management,
Institute of Industrial Sciences and Factory Systems,
Chemnitz University of Technology,
Chemnitz, Saxony, 09107, Germany

* Corresponding author. Tel.: +49-371-531-39869; fax: +49-371-531-839869. *E-mail address*: romina.poller@mb.tu-chemnitz.de.

Abstract

Due to the reasons of sustainability, energy efficiency becomes a more and more important objective for industrial companies. Among others, the term “energy management” is often mentioned as a practical instrument to raise energy efficiency. Because of the long-term influence at an early stage of the factory life cycle, factory planning provides an important contribution to realize company goals regarding energy efficiency. Until now, there is a lack of methodical concepts considering the combination of energy management and factory planning. In this paper, the interaction between both of these topics is described and by this, the meaning of energy management as an integral part of energy-efficient factories is underlined. Generally, energy management is used in the phase of factory operation to improve the energy performance, including energy efficiency, energy supply security, energy use and energy consumption. Besides, the integration of energy-related tasks in the factory planning process should also be realized as far as possible, e.g. regarding the purchase, distribution, storage and use of energy. This leads to a more systematic and holistic consideration of energy efficiency in organizational and technical processes of a company.

Keywords: energy management; energy efficiency; energy economy; factory planning; factory operation

1. Introduction

The most important objectives for industrial companies have always been costs, time and quality. In the last years, these objectives were extended by energy efficiency, which was triggered by increasing energy costs, environmental and political demands. However, methods and tools for energy saving and costs minimization for energy purchase as well as use of energy were hardly disseminated due to several reasons. Responsible for that were the low importance of energy costs for decades [1], the lack of legal constraints [2] and the lack of awareness for energy-related issues. At the same time, these points were also determining for the low importance of energy efficiency as a target criterion for operational decisions. The energy turnaround in Europe including the "20-20-20" targets is one reason for a gradual process of rethinking towards a more energy-efficient acting. In this context, companies realize the potential for improving energy efficiency by implementing a certified energy and environmental management system, which is interlinked to the tax savings in certain countries. This forces reactions by many companies. But only every other one had implemented an energy or environmental management system [3]. To manage the higher complexity of tasks, a variety of approaches have been developed during the last years. That was aroused by the extension of the business targets. These recommend how to reduce the energy consumption in production for the long-term. An integral part of these approaches is to implement a company’s *Energy Management* (EnM). In doing so, the sense of systemizing and organizing over the entire energy chain under ecological and economical target-settings is very important [4]. Especially for energy-intensive companies with a high proportion of energy related costs, the successful implementation of an effective EnM could provide a crucial competitive advantage [5]. Bruder [6] describes EnM as a holistic analysis, structuring and documentation of the process chain from the energy purchase to the energy consumption. However, that focus does not yet go far

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enough. In this paper, the consideration is being extended for the interaction of EnM and the factory planning process. The point of view of planning participants will be expanded by the connection between factory planning or factory operation and the requirements of EnM. For the same reason, the scope of duties as well as the possibilities of energy efficiency improvement will be extended. The relevance of this procedure is the higher suggestibility of energy efficiency in the beginning of the factory lifecycle instead of the later operation [2]. From this background, chosen contents and tasks of EnM should be connected to the factory planning process (see chapter 5).

2. Discussion on definitions

The term EnM and more subsequent terms are often used in different connotations. In the following, different perspectives will be reflected to point out the range of requirements, tasks and contents of EnM. Already in 1986, significant basics for energy project management were created by Winje and Hanitsch [7] and they are still valid today. Project management indicates a temporally limited project. The basic principle of EnM as a permanent management process is developed by Wohinz and Moor in 1989 [8]. Permanent management process means the consistency from purchasing to production up to product sales. In the 1990's, there was an increasing dissemination of environmental management systems. That enabled a growing understanding of EnM as a holistic corporate task [2]. Before that, EnM had been understood as a technical task for realizing energy analysis and continuous energy monitoring [9]. Additional goals like sustainability and transparency [10] followed gradually as well as aspects like organization design and development. This includes the integration of e.g. the nomination of an energy manager or the expansion of company's knowledge base [9]. Kals divided the usage of EnM in four levels, namely global, national, sectoral and operational EnM [11]. Within a company, EnM can be a functional part of the entire organisation or can be integrated into the various operational functions (e.g. production, logistics and facility management). In this context, the term *energy controlling* is also often used. According to Waltenberger [12], energy controlling is a subtask of EnM and includes the application of functions of controlling to special tasks of energy economy (e.g. price forecasts and energy reporting). EnM does not only refer to the use of energy, but also to upstream and downstream parts of the *energy conversion chain*, e.g. energy production and energy distribution. There's often a junction of questions of energy production, use and storage. EnM as an operational or technical task is to be distinguished from hardware and software solutions, which are often used synonymously for terms like systems for EnM or energy monitoring. These IT-solutions are designed for continuous collection and analysis of energy data and could include additional management support functions, such as the preparation of reports. An often used synonym for EnM is *load management*. It has the task to avoid peak loads in order to not exceed the contractual transfer performance of the energy supplier [5]. This is mainly achieved by temporal distribution or displacement of processes.

To create a uniform understanding of terms, a technical german committee developed a general definition of *EnM*: "foresighted, organised and systematic production, distribution and use of energy under ecological and economical target settings" [4]. This definition is used below. The related term *Energy Management System* (EnMS) means "all required organizational and informational structures, which are necessary for realization of EnM, including the technical resources" [4].

General requirements	• Establishing, implementing and improving the energy management system
Management responsibility	• Providing the necessary resources (including energy manager) • Ensure compliance with requirements
Energy policy	• Commitment to continual improvement of energy performance • Obligation to comply with legal requirements • Support the purchase of energy-efficient products and services • Documentation and communication within the organization at all levels
Energy planning	• **Energetic** evaluation by identifying areas with significant energy use with the help of measurements and identification of ways to improve the energy performance • Record and update of **energy basis** • Determination of **energy performance indicators** • Definition of strategic and operational **energy goals** and **action plans**
Implementation and operation	• Creating awareness and training of employees • Control of documents and processes of critical energy areas • Consideration of the energy performance in purchase and design of systems and devices
Checking	• Regular monitoring, measurements and analysis (energy evaluation, energy performance indicators, action plans, evaluation of current and expected energy consumption) • Internal auditing • Initiation of corrective and preventive actions
Management review	• Regular review of energy management system by the management

Fig. 1. Overview of requirements of EnMS according to ISO 50001 (short version)

3. Standards and guides for energy management

Due to international climate agreements and derived objectives, various national and international initiatives and programs for reduction of greenhouse gas emissions have been initiated in recent years. It has been shown that environmental and energy management standards are important tools to support the energy objectives. EnMS take up the topic of energy in a much more detailed form as environmental standards. These offer the possibility for systematic and permanent integration of efficient use of energy into business processes. The clear goal here is to increase the energy performance of the company. In recent years, several national standards and the European Standard EN 16001 for EnMS were created. The standards have a lot in common, i. a. general requirements, documentation, recording, energy policy, legal framework, strategic and operational objectives, project planning, actions, communication, awareness, training and monitoring. [13]

In 2011, the ISO 50001 [14] was published as a globally applicable standard by the International Organization for Standardization (ISO). At least in Europe, ISO 50001 replaced the standard EN 16001. The ISO 50001 has a lot in common with other management system standards such as ISO 9001 and ISO 14001, so requirements of this standard can be integrated in other management systems and the other way around. In addition to the standards listed, there are other supplements, standards, guidelines and energy management standards that were not developed by the (inter)national standard institutes [13]. In German-speaking countries it is in particular, the VDI Guidelines 4602 sheet 1 "Energy management - Terms and definitions" and sheet 2 "Energy management - Examples", which were also important when developing EN 16001 and ISO 50001 (see chapter 2). For the implementation of EnM in companies, various practical guides were published (e.g. [15], [16], [17]). These transmit the requirements of the standard in required actions. So it is getting more practical and understandable for practitioners.

4. Focus on energy management based on ISO 50001

The goal of EnM according to ISO 50001 is in particular to improve the energy performance of an organization. That means to reach measurable results of energy efficiency, energy use and energy consumption. As shown in chapter 3, the standard is arranged into existing management systems. It bases on the continual improvement process following the PDCA cycle (Plan-Do-Check-Act) and the integration of the (energy) management in the daily operations of the organization. First, energetic evaluations are completed in the planning stage (Plan). After that, some factors are determined, which include the energy baseline, energy performance indicators, strategic and operational energy goals and action plans. This is followed by the section of implementation (Do), where action plans are transferred to practice. During the monitoring section (Check) energy-related processes can be monitored, measured and documented. Measures for continual improvement of energy performance are performed in the improvement section (Act). The requirements for implementing, maintaining and improving the EnMS are divided in seven categories, as shown in figure 1. The probably most important category is energy planning, which leads to activities for a continuous improvement of the energy performance. Furthermore the standard provides statements about *WHAT* to do in order to successfully implement an EnMS. But *HOW* this is done in detail is not described or defined.

The organization determines the degree of range and timing of the continual improvement process in its sole discretion. It is based on economic, technological and other considerations. To ensure continual improvement, however, all premises and activities of the organization should be documented and observed.

5. Energy management as a tool for energy-efficient factories

5.1. Relevance

In the previous sections, the term EnM was narrowed and its objectives, content and focus were explained. This has shown that EnM is a very comprehensive and well-established tool to coordinate energy-related processes in a company. As shown in figure 2, there are substantial overlaps between EnM and planning as well as operating of energy-efficient factories among other regarding goals, measures, methods and structures. The EnM supports factory planning by provision of data and information, so that the planning process can be enriched with energy-related knowledge. This refers in particular to extension and re-planning projects of existing factories. Even with new planning projects, individual contents of EnM can be used e.g. determination of required energy, forecast of energy consumption. However, the details of energy data and information are lower than within existing planning objects. In factory operation, EnM supports the integration of energy issues into everyday business processes. The business potentials of linking between factory planning/ factory operation and EnM raised in chapter 1 will be discussed in this chapter to illustrate the role of the EnM as an essential component of energy-efficient factories.

Fig. 2. Overlap of EnM and factory planning or factory operation

5.2. Connection of activities of energy management and factory planning or factory operation

The described thematic overlaps between EnM and factory planning as well as factory operation will be explained in more detail by the combination of dual activities. Therefore, the requirements of ISO 50001 (see chapter 4) were adapt to the planning activities according to Schmigalla [18] and the contents of the following factory operation. Planning activities include systems analysis, designing, synthesis and integration. This is followed by the system realization. During *analysis*, the system will be determined. Furthermore, important parameters will be recorded in order to describe statements on the function and structure of the system. In the phase *basic engineering*, different options are set up. After comparing these options, one preferred alternative, which is gradually refined in the *detail engineering*, can be selected. The *implementation* considers the relationships between the system and its environment.

The identified interactions between the activities of the EnM and factory planning are shown in figure 3. Especially to be emphasised are the activities of *energy planning*. One action in this category is the evaluation of energy performance using quantitative systems analysis and belongs to the phase of *analysis* in factory planning process. With this evaluation the planning process has been enriched by energy-related knowledge. The use of the estimated future energy demands is another important fact, which is helpful for dimensioning the technical energy infrastructure.

These close relationships are again emphasizing the importance of an integrated view of the two action settings, factory planning or factory operation and EnM.

5.3. Function of energy management for factory operation

In addition to the planning aspects, EnM is an integral part of the operating management system of a company. Therefore, it is primarily applied in factory operation instead of factory planning. The EnM undertakes extensive tasks to improve the energy performance, thus reducing the environmental impact and the energy costs.

These activities can be roughly classified into the fields of man, technology and organisation (MTO) [19]. With technological focus, the EnM provides tools to determine and improve the energy efficiency, energy use and energy consumption for practical tools.

In addition to technological and organizational aspects, the subdivision by the MTO approach emphasizes the important role of social aspects in EnM. Measures of communication, awareness and competence are needed in the context of a successful implementation of management systems. Without them, significant miscalculations in the planning process or in factory operation are possible.

5.4. Trends of energy management

In accordance to the definition, operating EnM includes the purchasing, conversion, distribution and use of energy within the corporate limits. In considering the energy chain from producer to end-user, there are changes from an originally linear chain to an altering structure and even reflows.

This means that energy users no longer appear as energy consumers, but also as energy producers. This increases the proportion of small and decentralized energy producers. The main reasons are rising energy costs and the government's funding of renewable energy. From an economic point of view, technologies such as power plants for photovoltaic, solar thermal, wind or hydroelectric are now profitable. In addition, there is a trend for companies or municipalities to be targeted on energy self-sufficiency in order to decouple from rising energy prices and energy shortages [20]. However, the increasing number of decentralized energy producers and the seasonal variation in production stresses the supply networks significantly. As a result, the networks must be developed extensively.

By new developments such as intelligent power networks (Smart Grids) or virtual power plants (e.g. [21]) potentials of a flexible and decentralized energy production should be used together in a larger network. In structures like that, the factory will be an energy producer and energy storage device in addition to the function as energy customer.

This circumstance has created new economical, organizational and technological requirements for EnM. Figure 4 illustrates these coherences while showing an increasing networking of enterprises (shown at the level of corporate network and production facilities) and energy economy (simplified summary of outplant energy networks, producers, network operators and suppliers).

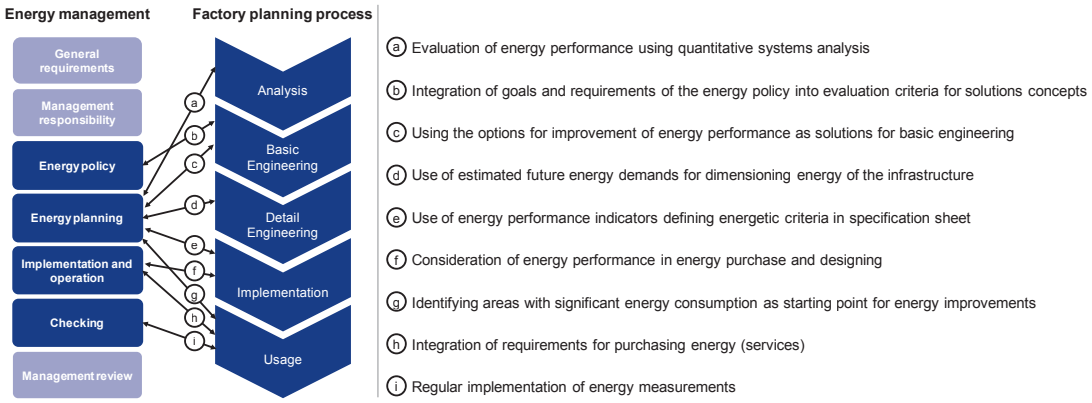

Fig. 3. Correlations of activities of EnM (ISO 50001) and factory planning process

The new challenge for EnM is to coordinate the internal processes from the production to the use at the company. This requires links between the individual departments and their installations and facilities. In addition, links are established with external organizations. This applies especially to the economic issues of energy purchase and energy sales (recovery into the energy network). In case of shortages, there are additional requirements of EnM. For factory planning and factory operation, the trends lead to new production structures and strategies in dynamic balancing between energy supply and energy demand offer an enormous potential.

5.5. Selected research topics within "Centre of Energy competence - Logistics and Factory Planning"

In order to explore the potentials of EnM as an integral part of energy efficient factories, supporting tools and methods are developed in the cluster of excellence "Energy-Efficient Product and Process Innovation in Production Engineering". The results are entered in "Centre of Energy Competence - Logistics and Factory Planning" (CEC-LF) at the Department of Factory Planning and Factory Management [22].

The goal of CEC-LF is to provide an interdisciplinary research, development and training platform for exploiting energy efficiency potentials in logistics and factory planning. A holistic approach to the relationships between processes, machines and systems of the factory is aspired. The two main components of the CEC-LF are the factory demonstrator as realistic production environment and the modular qualification system that associates training methods and contents to target groups. A requirement of interdisciplinary studies for energy efficiency is the transparency of factories' energy flow system. Therefore, an approach to analyze and evaluate the energy consumption of logistics systems was developed. Furthermore, temporary and stationary energy measuring points were integrated to establish a comprehensive energy monitoring (step of *checking*, see figure 3). Collected energy data are consolidated into operating condition-based energy information of each system. These data and information can be summarized and visualized by the developed tool "energy cards" [23]. The developed energy knowledge for energy efficiency-oriented factory planning is the starting point for subsequent qualification courses in the CEC-LF (step of *implementation* and *operation*, see figure 3).

6. Summary

In this article, the importance of EnM was highlighted as a tool for coordinating energy-related processes. The range of definitions and the important contents of the topic EnM were explained. Linking factory planning and factory operation with the principles of EnM, may contain overlaps in content.

In this context, chosen overlapping contents between EnM and factory planning were shown and illustrated by examples. Furthermore, future development trends of EnM were presented. These trends induce the increasing networking of industrial companies with the energy economy, which determine additional requirements and enlarged tasks of EnM.

In a holistic approach by linking factory planning and factory operation with EnM, it turned out, that there is a considerable scope to increase the potentially energy-related performance. The development of these potentials contributes to energy-efficient factories. To illustrate this, selected research topics were presented, which focus on the development of tools to support the EnM.

The studies have been shown that EnM is an integral part of energy-efficient factories. Future challenges are a holistic view of requirements of EnM in relation to factories, corporate networks, etc. and stronger linking of EnM functions and factory planning processes.

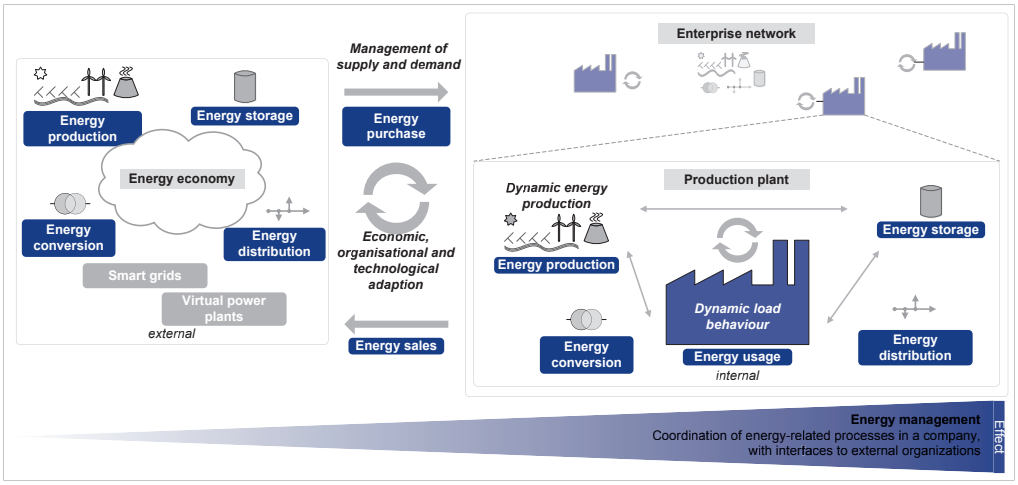

Fig. 4. Organizational networking of enterprises and energy economy

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